B4 · Predict reactions and investigate

Completed notes | Notes 1/3

Use test results and the Data Booklet reduction table to predict direction, then judge an investigation’s conclusions.

1. Evidence and strength

Separate observations from their explanation

Balancing cannot tell us which way a reaction goes. $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ balances, and so does its reverse. A balanced equation does not by itself prove a **spontaneous reaction in the written direction**. Spontaneous means it goes on its own. It does not mean fast.

Here are two example test results. Your class did not measure them. A strip of zinc in a Cu^{2+} solution gets a copper coating. A strip of copper in an Ag^{+} solution gets a silver coating. A new metal coating is evidence that dissolved ions **gain electrons** to become metal. The electrons came from the metal that dissolved.

So a metal that gives electrons to another metal’s ions is the stronger reducing agent. The two comparisons link through copper. Reducing agents rank **Zn > Cu > Ag**. The matching ions run the other way: oxidizing agents rank **Ag^{+} > Cu^{2+} > Zn^{2+}**. A metal and its ion have different roles.

On the diploma: build the order from the pairs, and say which metal was the reducing agent in each pair. Write the exact formula, such as Ag^{+}, not just silver.

Watch: What you would see: bubbles of hydrogen gas (Alberta Chemistry Teacher, “Chemistry 30 - Predicting redox reaction from species in the reduction table”, 11:01)

Watch: Observations to report: bubbles, pop test, litmus (Alberta Chemistry Teacher, “Chemistry 30 - Example: predicting redox reaction and observations of reactants and products”, 12:03)

Watch: What a falling H^{+} does to the pH (Alberta Chemistry Teacher, “Chemistry 30 - Example: predicting redox reaction and observations of reactants and products”, 12:22)

Read a reduction row

Every row in the Alberta Chemistry 30 Data Booklet table of standard reduction potentials is written as a reduction. The electrons are on the **left**. The oxidizing agents are on the left, and the strongest is at the top. The reducing agents are on the right, and the strongest is at the bottom. A metal on the right side of a row can act as a reducing agent, but only when you read that row **reversed**.

An oxidizing agent reacts spontaneously with a reducing agent that is below it in the table. Ag^{+} is above Cu, so they react. Zn^{2+} is below Cu, so they do not. That is why a copper container can hold a Zn^{2+} solution.

You can only choose substances that are really in the beaker. List every ion, any metal, and water. An acidic or “acidified” solution also has H^{+}, and a basic solution has OH^{-}. A

strong oxidizing agent elsewhere in the booklet is not in your beaker. It is like picking a team from the people who showed up. Choose the strongest **oxidizing agent** and **reducing agent** from what is in the beaker.

Label the diagram with the order of reducing agents and the order of oxidizing agents. These are example results, not measurements from a class experiment.

On the diploma: use the substances given in the question, not every row of the table.

Watch: The forward arrow in the table is the reduction (Alberta Chemistry Teacher, “Chemistry 30 - Predicting redox reaction from species in the reduction table”, 2:44)

Watch: Flip the row to write the oxidation (Alberta Chemistry Teacher, “Chemistry 30 - Predicting redox reaction from species in the reduction table”, 3:10)

Zn in Cu^{2+}: copper coating. Cu in Ag^{+}: silver coating.

Metal donors, strongest first: Zn > Cu > Ag

Ion acceptors, strongest first: Ag^{+} > Cu^{2+} > Zn^{2+}

Example results. Your class did not measure them.

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2. What the table values mean

Energy per charge, measured from one starting point

The symbol E means **electric potential**, measured in volts. The small ° means **standard conditions**: 1.0 mol/L, 25.00 °C and 101.325 kPa.

A voltage is the **energy for each unit of charge**. One volt means **one joule per coulomb**, and a coulomb is a unit of electric charge. For 150 J moved by 100 C, 150 ÷ 100 = **1.50 V**. Double both and 300 ÷ 200 is still **1.50 V**.

Every table value is measured from the same starting point, the hydrogen half-reaction, $2H^+ + 2e^- \rightarrow H_2$, which is given **0.00 V**. Each half-reaction is printed as a **reduction**. A more positive value means a stronger pull on electrons under table conditions.

A table value is not a voltage you could read from one beaker. Voltage compares a **reducing agent–oxidizing agent pair**. In this lesson, putting a metal in a solution gives us a prediction only. It does not measure the voltage of a real cell.

On the diploma: remember the table lists reductions only. Changing a coefficient never changes E°.

Pick the roles first, then subtract

Use E°reaction = E° of the **oxidizing agent** minus E° of the **reducing agent**. We subtract because the reducing agent's half runs **backward as oxidation**. Do not just take larger minus smaller.

A positive answer means the written direction is spontaneous under standard conditions. A negative answer means **the reverse** is spontaneous. It tells you nothing about **speed**. Doubling the amounts does not change the energy per charge, so never multiply E° by the coefficients.

On the diploma: a common wrong option gives $Cu + Zn^{2+}$ a positive E° by subtracting in the wrong order. Check which one is the reducing agent first.

Watch: List everything that is present (Alberta Chemistry Teacher, "Chemistry 30 - Predicting redox reaction from species in the reduction table", 0:03)

Watch: Label the oxidizing and reducing agents (Alberta Chemistry Teacher, "Chemistry 30 - Predicting redox reaction from species in the reduction table", 1:33)

Watch: Find the best of each (Alberta Chemistry Teacher, "Chemistry 30 - Predicting redox reaction from species in the reduction table", 2:24)

A mixture changes the choice, not the method

Suppose a beaker holds Zn(s), Cu(s), Ag^+ and Cu^{2+}. Use only what is present. The strongest reducing agent is **Zn** and the strongest oxidizing agent is **Ag^+**. Choose them before you write any equation.

The reaction is $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$. $E° = +0.80 - (-0.76) =$ **+1.56 V**. Cu and Cu^{2+} are still in the mixture, but they are not part of this **net equation**.

This predicts which reaction the strongest pair starts with. It does not tell you the final mixture, or the order other reactions would follow.

Watch: Zinc in hydrochloric acid: list everything present (Alberta Chemistry Teacher, “Chemistry 30 - Predicting redox reaction from species in the reduction table”, 6:02)

Watch: Watch for pairs such as chloride and water (Alberta Chemistry Teacher, “Chemistry 30 - Predicting redox reaction from species in the reduction table”, 9:37)

Watch: Build the list from a longer formula list (Alberta Chemistry Teacher, “Chemistry 30 - Example: predicting redox reaction and observations of reactants and products”, 0:36)

Watch: Tin(II) is both an oxidizing and a reducing agent (Alberta Chemistry Teacher, “Chemistry 30 - Example: predicting redox reaction and observations of reactants and products”, 2:22)

Watch: The common mistake: missing tin(II) as a reducing agent (Alberta Chemistry Teacher, “Chemistry 30 - Example: predicting redox reaction and observations of reactants and products”, 7:42)

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3. Predict, then test the claim

Table values

From the Alberta Chemistry 30 Data Booklet, printed as reductions: Ag^+/Ag **+0.80 V**; Cu^{2+}/Cu **+0.34 V**; Zn^{2+}/Zn **-0.76 V**. These hold at standard table conditions, which are 1.0 mol/L solutions at 25.00 °C. A more positive value means a stronger pull on electrons.

For the reaction as written, E°reaction = E° of the **oxidizing agent** minus E° of the **reducing agent**. We subtract because the reducing agent runs its table row backwards, as an oxidation. A positive result means the written direction is spontaneous. A negative result means the reverse is spontaneous.

For $Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$, Ag^+ is the oxidizing agent and Cu is the reducing agent: +0.80 - (+0.34) = **+0.46 V**. A volt is one joule of energy per coulomb of charge, so it is a ratio. Do not multiply E° when you multiply a half-reaction's coefficients.

On the diploma: check which value is the oxidizing agent's and which is the reducing agent's before you subtract.

Direction matters

For the proposed $Cu + Zn^{2+} \rightarrow Cu^{2+} + Zn$, Zn^{2+} is the oxidizing agent and Cu is the reducing agent: -0.76 - (+0.34) = **-1.10 V**. Always taking larger minus smaller skips the choice of reducing agent and oxidizing agent. It can answer the wrong direction.

The negative sign means the reverse, Zn with Cu^{2+}, is spontaneous at +1.10 V. The sign tells direction, not speed. No visible change in a short trial is **not proof that reaction is impossible**, because the reaction might be too slow to see.

On the diploma: a sign-flipped answer is a common wrong option, so match the sign to the reducing agent and the oxidizing agent.

Watch: The spontaneity rule: oxidizing agent above reducing agent (Alberta Chemistry Teacher, "Chemistry 30 - Predicting redox reaction from species in the reduction table", 4:59)

Watch: Below means it does not happen by itself (Alberta Chemistry Teacher, "Chemistry 30 - Predicting redox reaction from species in the reduction table", 5:18)

Watch: Check the spontaneity rule at the end (Alberta Chemistry Teacher, "Chemistry 30 - Example: predicting redox reaction and observations of reactants and products", 10:09)

A fair comparison and a supported conclusion

In a fair test, change one metal-ion pair at a time. Keep the concentration, volume, strip size, temperature and time **the same**. Add a **control**: a test where nothing should happen, such as Cu in Cu^{2+}.

A good conclusion gives a claim, then the evidence, then an **explanation of who gave electrons**. Name the metal, the ion that changed and who gave the electrons. The simulation follows fixed rules, so running it again adds no new **evidence**. It does not test hands-on lab skill.

On the diploma: tell an observation, such as seeing a deposit, from an inference, such as saying a metal is the stronger reducing agent. Cite the actual comparisons in your answer.

B4 · Worked practice

Predict reactions and investigate | Questions 1-2 of 12

State symbols: (s) solid, (aq) dissolved in water, (l) liquid, (g) gas. Use the supplied reaction and conditions. B4 values name the Alberta Chemistry 30 Data Booklet table where used.

B4-P01 · Easy · In the reaction $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$, name the reducing agent and the oxidizing agent. Which metal is the stronger reducing agent, Zn or Cu?

1. Zn gives electrons and Cu^{2+} takes them. Zinc reduces the copper ions to Cu metal.

2. So Zn is a stronger reducing agent than Cu. Do not put Cu^{2+} in the list of reducing agents. It is the oxidizing agent.

B4-P02 · Easy · Test results: Zn gives electrons to Cu^{2+}, and Cu gives electrons to Ag^{+}. Put Zn, Cu and Ag in order as reducing agents, strongest first. Say which two results support your order.

1. Zn gives electrons to Cu^{2+}, so Zn > Cu. Cu gives electrons to Ag^{+}, so Cu > Ag.

2. Copper is in both results, so it links them: Zn > Cu > Ag. This order comes from two tests, not three.

B4 · Worked practice

Predict reactions and investigate | Questions 3-4 of 12

B4-P03 · Easy · The metals are in the order Zn > Cu > Ag as reducing agents. Put their ions, Ag^+, Zn^{2+} and Cu^{2+}, in order as oxidizing agents, strongest first.

1. The order of the oxidizing agents is $Ag^+ > Cu^{2+} > Zn^{2+}$.

2. Each ion takes electrons and becomes its metal. A metal that gives electrons easily makes an ion that takes them back poorly. So the two orders run opposite ways.

B4-P04 · Easy · A beaker contains Cu(s), Ag^+(aq) and nitrate ions. The nitrate ions are spectator ions here. Which two substances could react in a redox reaction? Explain why Zn cannot be one of them.

1. The pair is Cu metal, as the reducing agent, and Ag^+, as the oxidizing agent. Nitrate is a spectator ion, so it does not change.

2. Zn is not in the beaker. A stronger reducing agent in the table cannot react if it is not there.

B4 · Worked practice

Predict reactions and investigate | Questions 5-6 of 12

B4-P05 · Medium · Use these rows from the Data Booklet table of standard electrode potentials: $Ag^+ + e^- \rightarrow Ag$, +0.80 V; $Cu^{2+} + 2e^- \rightarrow Cu$, +0.34 V; $Zn^{2+} + 2e^- \rightarrow Zn$, -0.76 V. The conditions are standard: 25 °C and 1.0 mol/L solutions. Copper metal is put in a solution of Ag^+. Calculate E° for the reaction and write the balanced net equation. Is the reaction spontaneous?

1. Ag^+ is the oxidizing agent and Cu is the reducing agent. In the table, Ag^+ is above Cu. E° = +0.80 - (+0.34) = +0.46 V.

2. $Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$. The value is positive, so the reaction is spontaneous under standard conditions.

B4-P06 · Medium · Use these rows from the Data Booklet table of standard electrode potentials: $Ag^+ + e^- \rightarrow Ag$, +0.80 V; $Cu^{2+} + 2e^- \rightarrow Cu$, +0.34 V; $Zn^{2+} + 2e^- \rightarrow Zn$, -0.76 V. The conditions are standard: 25 °C and 1.0 mol/L solutions. Calculate E° for the reaction $Cu + Zn^{2+} \rightarrow Cu^{2+} + Zn$. Is the reaction spontaneous as written?

1. In the reaction as written, Zn^{2+} is the oxidizing agent and Cu is the reducing agent. E° = -0.76 - (+0.34) = -1.10 V.

2. The value is negative, so the reaction is not spontaneous as written. The reverse reaction is spontaneous. Subtracting the smaller number from the larger would answer the reverse question.

B4 · Worked practice

Predict reactions and investigate | Questions 7-8 of 12

B4-P07 · Medium · Use these rows from the Data Booklet table of standard electrode potentials: $Ag^+ + e^- \rightarrow Ag$, +0.80 V; $Cu^{2+} + 2e^- \rightarrow Cu$, +0.34 V; $Zn^{2+} + 2e^- \rightarrow Zn$, -0.76 V. The conditions are standard: 25 °C and 1.0 mol/L solutions. Zinc metal is put in a solution of Ag^+. Write the balanced equation and calculate E°. A student doubles +0.80 V because two Ag^+ are needed. Explain the mistake.

1. $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$. Zn loses two electrons, and two silver ions take one each.

2. E° = +0.80 - (-0.76) = +1.56 V. Do not multiply E° when you multiply a half-reaction. E° is the energy for each unit of charge. More silver does not change it.

B4-P08 · Medium · A simulation shows the same result every time a test is replayed. Can five replays tell you how much a real experiment changes from try to try? Say what the replays can check, and one thing they cannot measure.

1. Five replays can check that the simulation gives the same result for the same input.

2. They are not separate real measurements. So they cannot show the effect of a dirty metal surface, the timing, the temperature or the concentration. A simulation follows fixed rules.

B4 · Worked practice

Predict reactions and investigate | Questions 9-10 of 12

B4-P09 · Challenging · Test results, all under the same conditions: a strip of metal A in B^{2+} solution gets a coating of metal B. A strip of metal B in C^{+} solution gets a coating of metal C. Predict what happens when A is put in C^{+} solution. Write the balanced equation. A forms A^{2+}. Explain how the two results lead to your prediction.

1. The tests show A > B and B > C as reducing agents. So A > C, and A will reduce C^{+}.

2. $A(s) + 2C^{+}(aq) \rightarrow A^{2+}(aq) + 2C(s)$. Two C^{+} ions take one electron each, which matches the two electrons A loses. This prediction is for the same conditions as the tests.

B4-P10 · Challenging · Two tests compare Zn in Cu^{2+} solution with Cu in Ag^{+} solution. They use different concentrations, different surface areas and different times. Name three things to keep the same so the comparison is fair. Explain why a test with a metal in a solution of its own ion helps.

1. Keep the ion concentration, the surface area of the metal and the time the same. Also keep the temperature and the volume of solution the same.

2. Zn in Zn^{2+}, or Cu in Cu^{2+}, shows no change. This is a control. It shows that any change in the other tests comes from the metal and the ion being different. A control does not remove every possible error.

B4 · Worked practice

Predict reactions and investigate | Questions 11-12 of 12

B4-P11 · Challenging · Use these rows from the Data Booklet table of standard electrode potentials: $Ag^+ + e^- \rightarrow Ag$, +0.80 V; $Cu^{2+} + 2e^- \rightarrow Cu$, +0.34 V; $Zn^{2+} + 2e^- \rightarrow Zn$, -0.76 V. The conditions are standard: 25 °C and 1.0 mol/L solutions. A student reports $E° = +1.10$ V for $Cu + Zn^{2+} \rightarrow Cu^{2+} + Zn$, by subtracting -0.76 from +0.34. Explain the mistake. Give the correct value with its sign. Which reaction does +1.10 V really describe?

1. The student used Cu^{2+} as the oxidizing agent, but the beaker has Cu metal. In the reaction as written, the oxidizing agent is Zn^{2+}.

2. For the reaction as written, -0.76 - (+0.34) = -1.10 V. The value +1.10 V is for $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$, the reverse reaction.

B4-P12 · Challenging · A lab record says: a clean Cu strip in Ag^+ solution gets a silver-coloured coating. In a control, Cu in Cu^{2+} solution shows no coating. Write a conclusion about the electrons that the record supports. Give two limits of the evidence.

1. The coating fits Ag^+ taking electrons from Cu and forming Ag metal, while Cu is oxidized to Cu^{2+}. The control supports this, because the coating forms only when the metal and the ion are different.

2. Colour alone does not prove what the coating is. A chemical test would make the claim stronger. The record also gives no speed and no change in mass.

3. No visible change in the control is an observation. It does not prove that no reaction at all can happen.